جامعة بيرزيت
BIRZEIT UNIVERSITY

# Reinforced Concrete Design I
# ENCE 335
## Column Design

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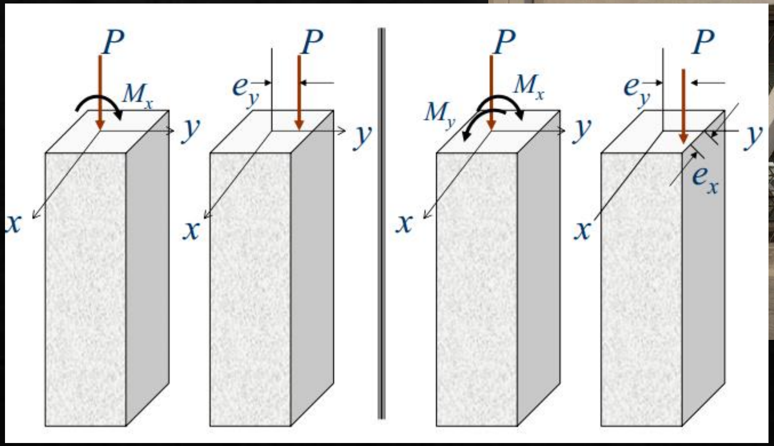
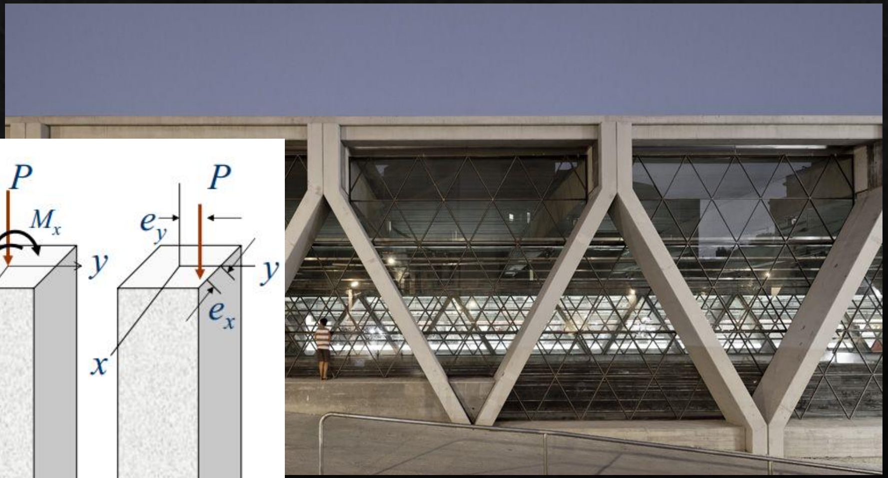
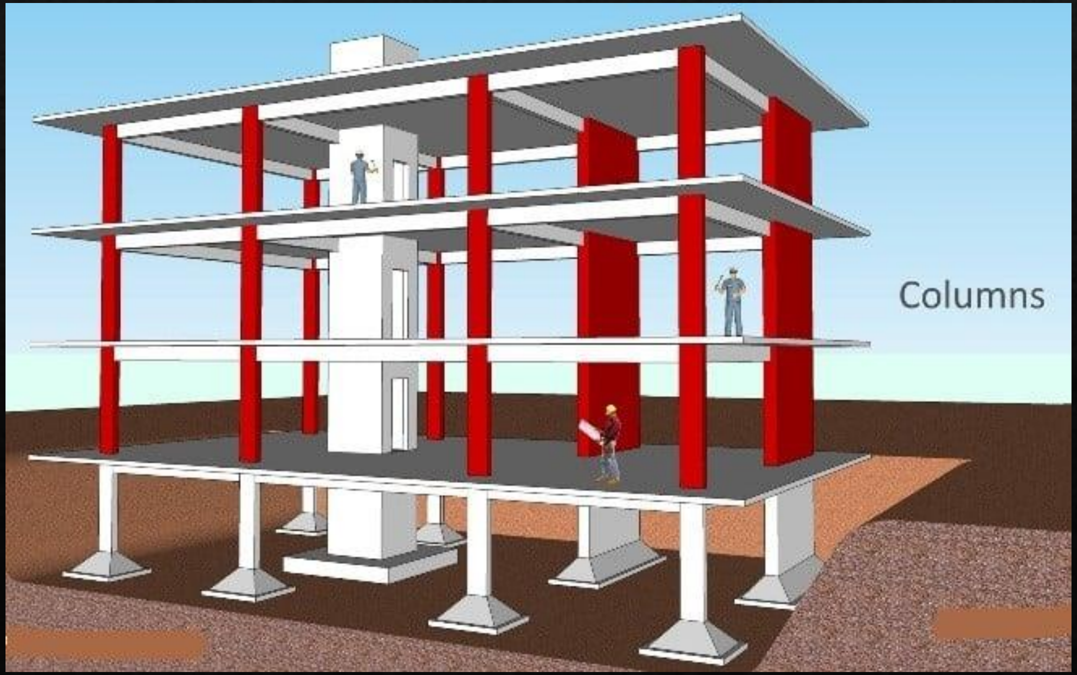
# Columns

- Columns are defined as members that carry load mainly in compression
- Columns may carry bending moments about one or two axes of the cross-section
- In some cases, tensile forces may develop in columns





# Behavior of Columns

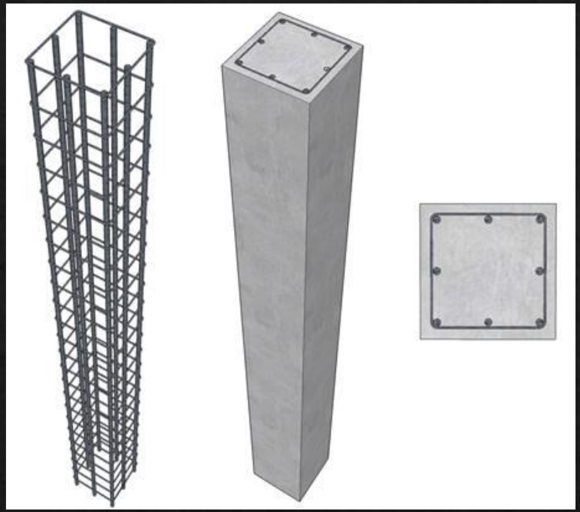
- Types of columns
  - Short columns

    lateral dimensions are very large compared to its length (or height). Generally fail due to compression (crushing of concrete)

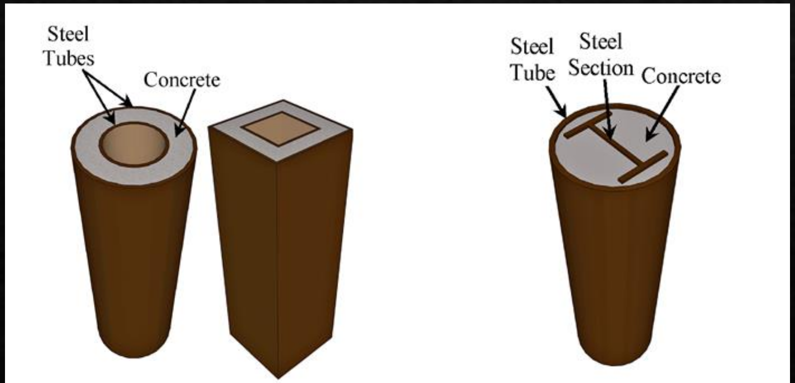
  - Long (slender) columns

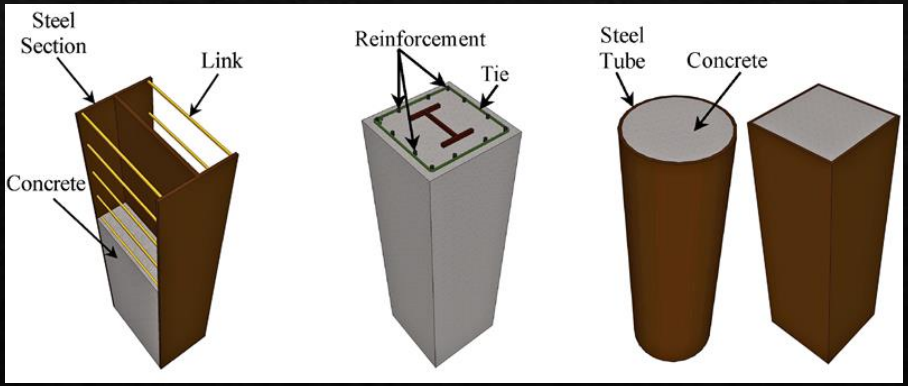
    lateral dimensions are small compared to its length. Generally fails by buckling

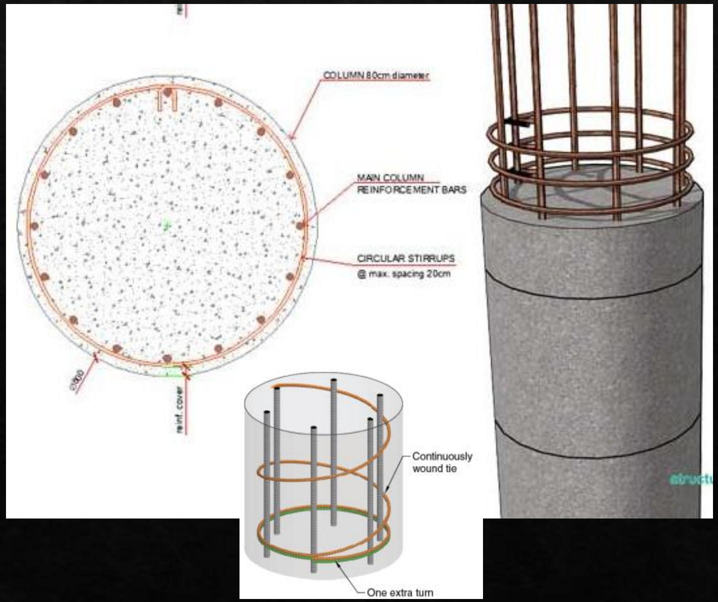

# Columns



- Types of RC columns
  - Concrete reinforced with longitudinal bars and lateral ties
  - Concrete reinforced with longitudinal bars and continuous spiral
  - Composite concrete members with structural steel shapes, such as; I-sections, tubes, or pipes. With or without longitudinal bars and lateral ties

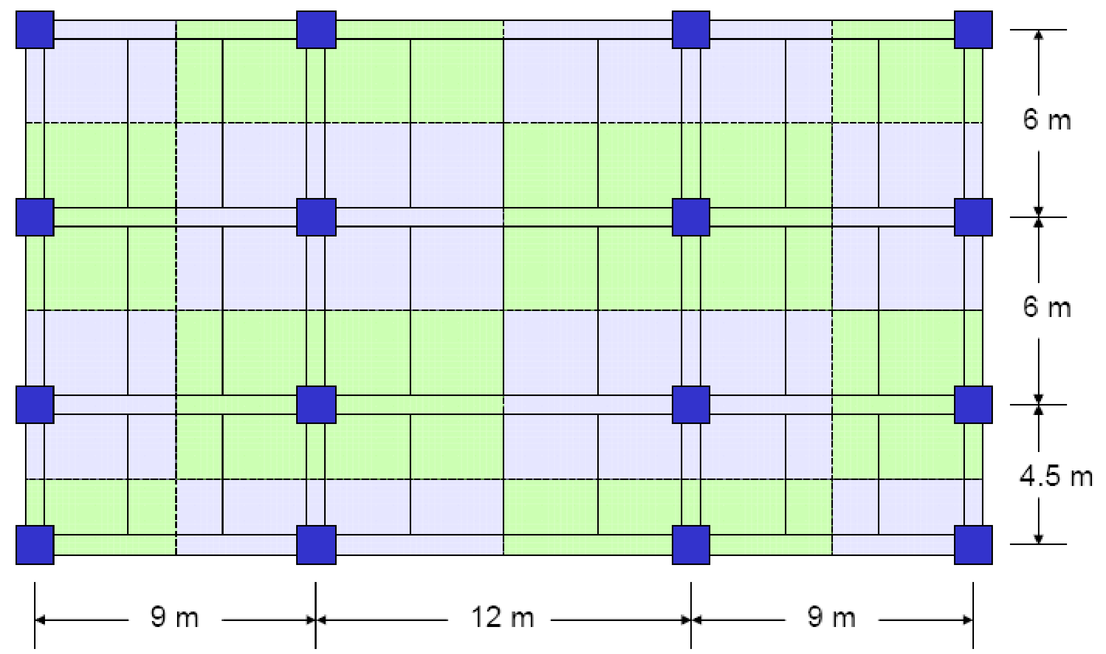


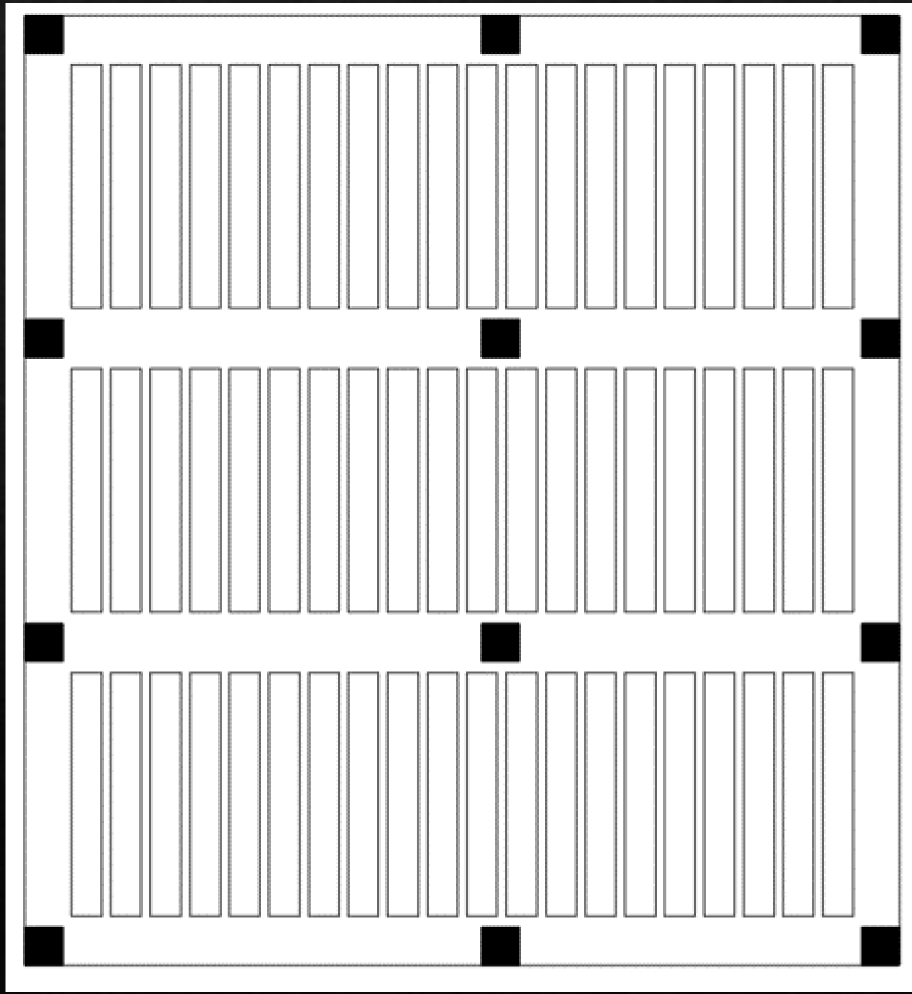



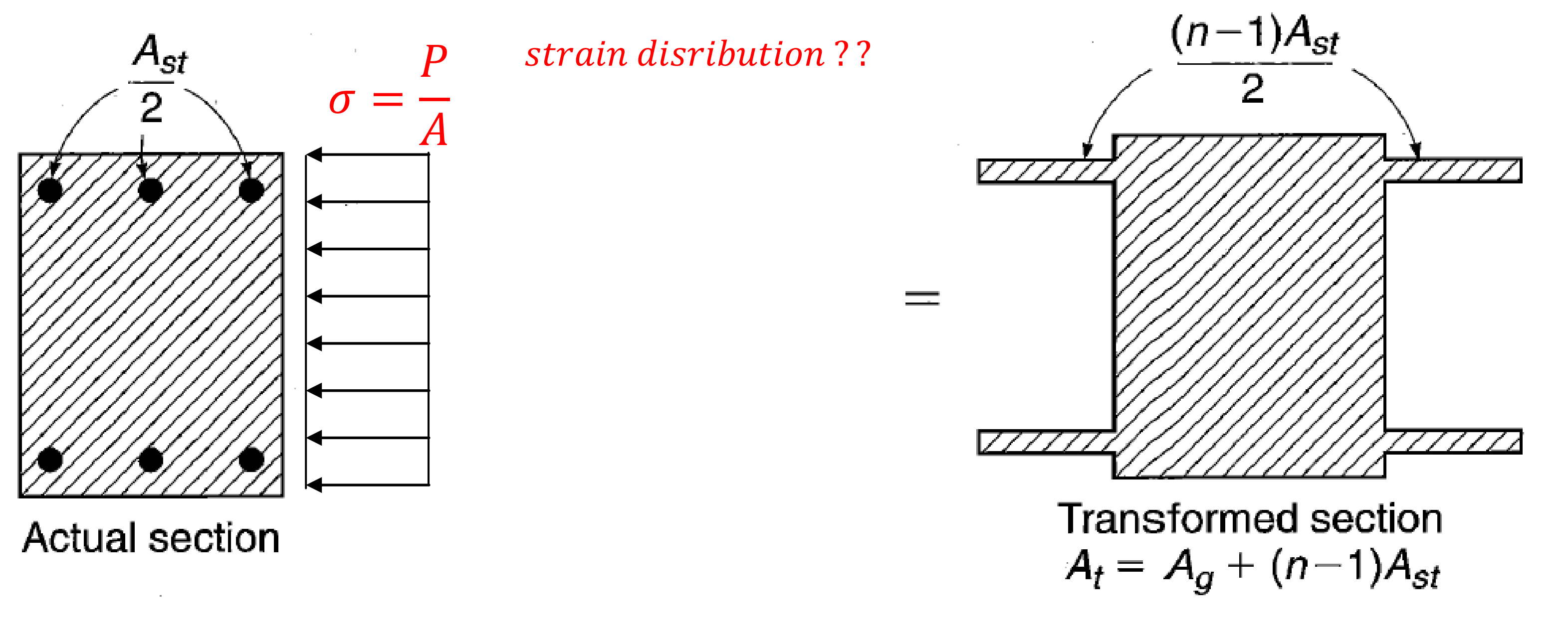
# Load Calculation

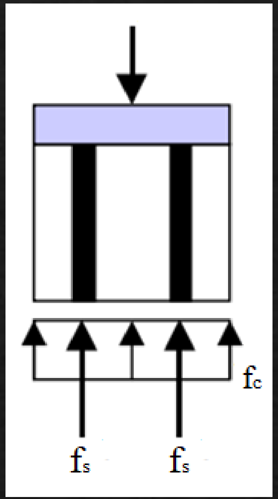
- Reaction of beam supports
- Frame analysis
- Tributary area



# Concentric Short RC Columns




$$P = f_c\left(A_g + (n-1)A_s\right)$$

Where: $f_c$ is stress in *concrete*

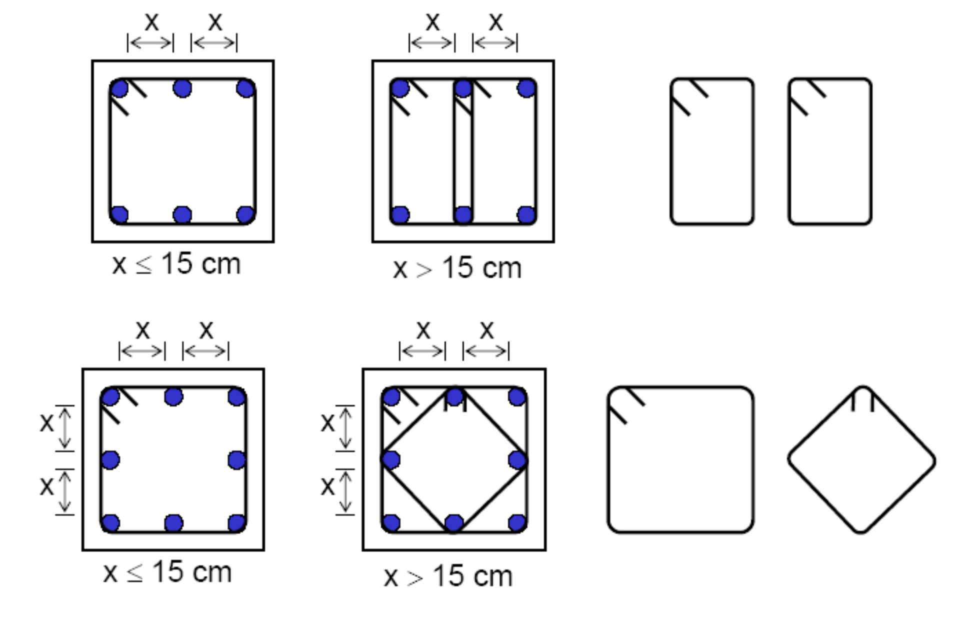
$$f_s =$$

$$P_n = 0.85 f_c'\left(A_g - A_s\right) + f_y\, A_s$$

$$\phi P_n \geq P_u$$

# ACI requirements for Columns

- Strength reduction Factor: Spiral: $\varphi = 0.75$ , Tied: $\varphi = 0.65$
- Steel reinforcement ratio $0.01 < \rho = \frac{A_S}{A_g} < 0.08$ , generally $\rho \leq 0.04$
- Min number of bars:
  - Rectangular: 4 bars
  - Circular: 6 bars
- Min clear spacing $S_{min} = \max\begin{cases} 1.5\, d_b \\ 40\ mm \end{cases}$
- Max spacing between bars unsupported with ties $S_{max} = 150\ mm$
- Clear cover : External 50 mm. internal 40 mm
- Accidental eccentricity :




To account for accidental eccentricity, the design axial strength of a section in pure compression is limited to 80 to 85 percent of the nominal axial strength

$$\phi P_n = r\ \phi\left[0.85\ f_c'\left(A_g - A_{st}\right) + f_y A_{St}\right]$$

r = Reduction factor to account for accidental eccentricity

r = 0.80 ( tied )

r = 0.85 ( spiral )

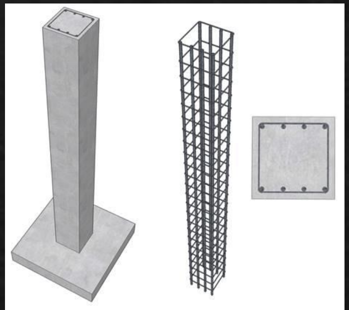
Table 21.2.2—Strength reduction factor φ for moment, axial force, or combined moment and axial force

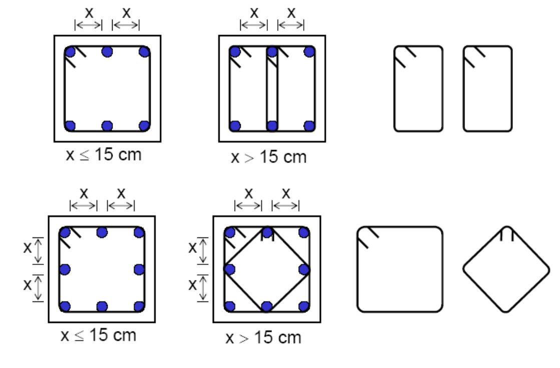
| Net tensile stain $\varepsilon_t$ | Classification | φ — Type of transverse reinforcement: Spirals conforming to 25.7.3 | | Other | |
|---|---|---|---|---|---|
| $\varepsilon_t \leq \varepsilon_{ty}$ | Compression-controlled | 0.75 | (a) | 0.65 | (b) |
| $\varepsilon_{ty} < \varepsilon_t < \varepsilon_{ty} + 0.003$ | Transition[1] | $0.75 + 0.15\frac{(\varepsilon_t - \varepsilon_{ty})}{(0.003)}$ | (c) | $0.65 + 0.25\frac{(\varepsilon_t - \varepsilon_{ty})}{(0.003)}$ | (d) |
| $\varepsilon_t \geq \varepsilon_{ty} + 0.003$ | Tension-controlled | 0.90 | (e) | 0.90 | (f) |

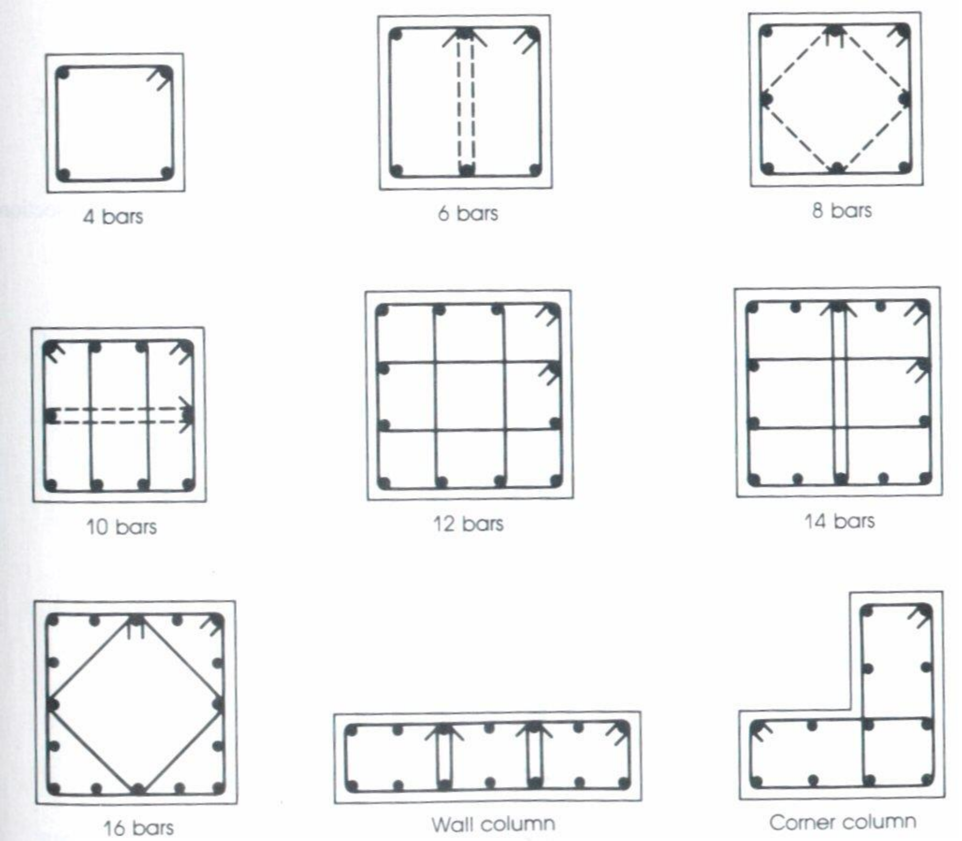
[1]For sections classified as transition, it shall be permitted to use φ corresponding to compression-controlled sections.

# ACI requirements for Columns

- Lateral ties and spirals
  - Ties
    - Size:
      - ϕ10 bar if longitudinal bar ϕ32 or smaller
      - ϕ12 bar if longitudinal bar ϕ36 or larger
      - ϕ12 bar if longitudinal bars are bundled
    - Max spacing
      - $\min\begin{cases}16d_b\\48\,d_t\\B\end{cases}$



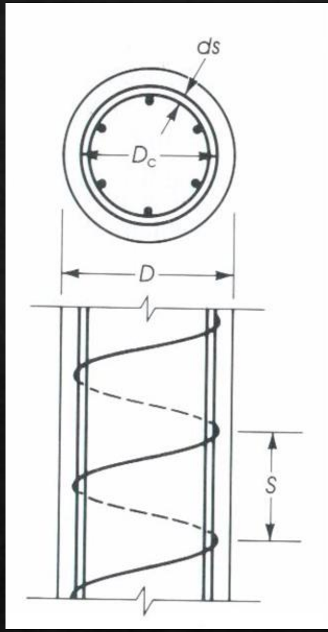


# ACI requirements for Columns

- Lateral ties and spirals
  - Spirals
    - Size:
      - $> \phi 10$ bar
    - Spacing
      - Minimum 25 mm or $d_b$
      - Maximum 75 mm
      - The volumetric spiral reinforcement ratio $\rho_s$

$$\rho_s = \frac{4A_{sp}}{D_c s} > 0.45\left(\frac{A_g}{A_{ch}} - 1\right)\frac{f_c}{f_y}$$



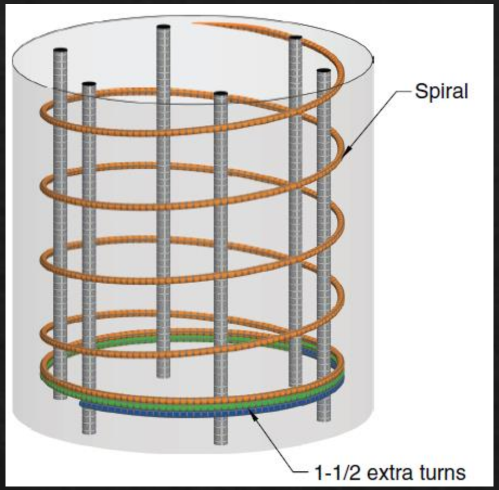




**TABLE A.14**
**Size and pitch of spirals, ACI Code, mm**

Size → 10–65 ← Pitch (spacing)

| Diameter of Column, mm | Out to Out of Spiral, mm | $f'_c$, MPa: 21 | 28 | 35 | 42 |
|---|---|---|---|---|---|
| $f_y$ = 420 MPa | | | | | |
| 350, 375 | 270, 295 | 10–65 | 10–50 | 13–70 | 13–55 |
| 400–475 | 320–395 | 10–65 | 10–50 | 13–70 | 13–60 |
| 500 | 420 | 10–70 | 10–50 | 13–70 | 13–60 |
| 525–725 | 445–645 | 10–70 | 10–50 | 13–75 | 13–60 |
| 750 | 670 | 10–70 | 10–50 | 13–75 | 13–65 |
| $f_y$ = 550 MPa | | | | | |
| 350–425 | 270–345 | 10–85 | 10–65 | 10–50 | 13–75 |
| 450, 475 | 370, 395 | 10–85 | 10–65 | 10–50 | 13–80 |
| 500–550 | 420–470 | 10–85 | 10–65 | 10–55 | 13–80 |
| 575–700 | 495–620 | 10–85 | 10–70 | 10–55 | 13–80 |
| 725, 750 | 645, 670 | 10–85 | 10–70 | 10–55 | 13–85 |

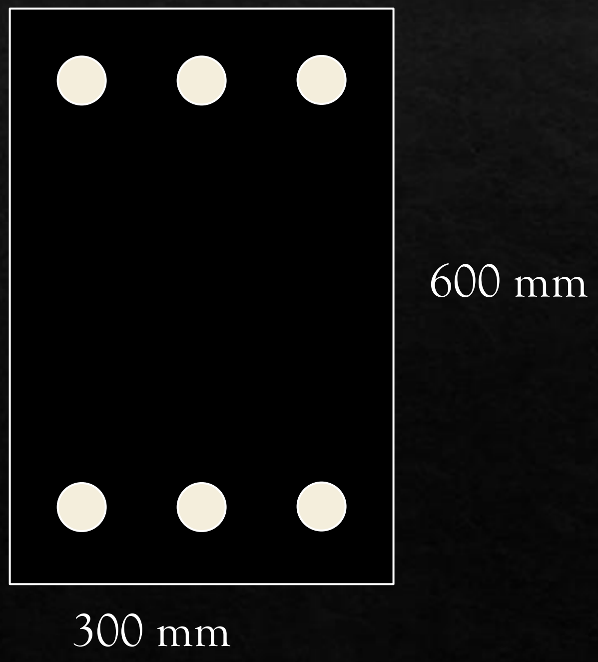
# Column Design

- Example

A non-slender column is subjected to axial load only. It has the geometry shown and reinforced with 6ϕ30 as shown. Calculate the maximum ultimate load the column can support.

Use fy = 420 MPa and fc’ = 28 MPa

$$\phi P_n = r\ \phi\left[0.85\ f_c'\left(A_g - A_{st}\right) + f_y A_{St}\right]$$



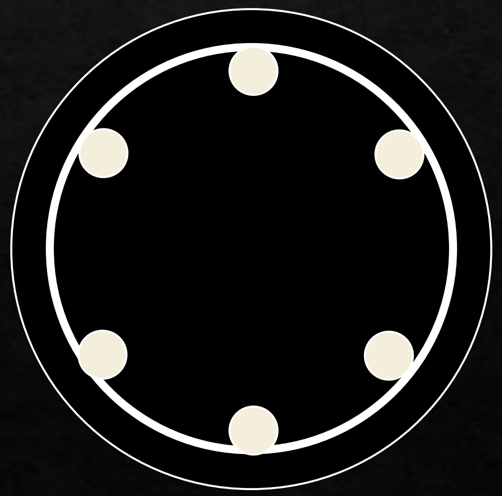
# Column Design

- Example

A non-slender circular spiral column with a diameter of 450 mm is subjected to axial load only. It has the geometry shown and reinforced with 6ϕ28 as shown. Calculate the maximum ultimate load the column can support.

Use fy = 420 MPa and fc' = 28 MPa

$$\phi P_n = r\,\phi\left[0.85\,f_c'\left(A_g - A_{st}\right) + f_y A_{st}\right]$$



Compare with Example 1 !!!

# Column Design

- Example

  Design a non-slender square column which is subjected to a concentric 2300 kN and 1335 kN dead and live loads, respectively.

  [Use $\rho = 0.02, f_y = 420\ MPa\ and\ f_c' = 28\ MPa$]

$$\phi P_n = r\ \phi[0.85\ f_c'(A_g - A_{st}) + f_y A_{st}]$$

$$P_u = 1.2 * D + 1.6\ L = 4896\ kN$$

$$A_{st} = 0.02\ A_g, r = 0.8\ , \phi = 0.65$$

$$\phi P_n = 0.8 * 0.65[0.85\ f_c'(A_g - 0.02A_g) + f_y * 0.02A_g$$

$$4896 * 10^3 = 0.8 * 0.65 * [0.85 * 28 * (0.98A_g) + 420 * 0.02 * A_g]$$

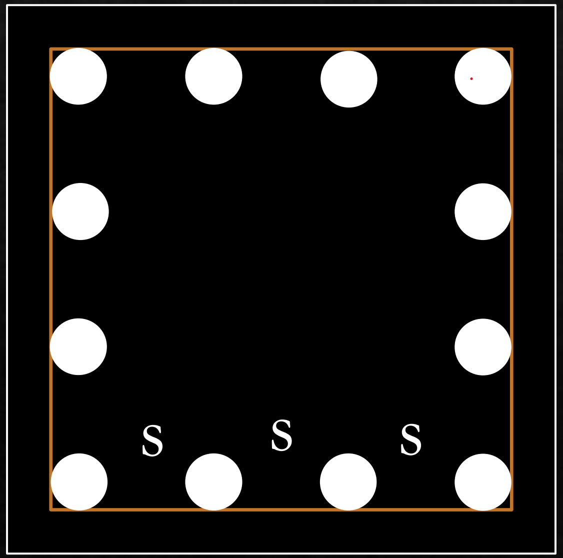
$$A_g = 296790.6\ mm^2 \rightarrow B = 544.8\ mm \sim 550\ mm$$

Use this value and solve for $A_S = 5592\ mm^2$

$$use\ 12\phi 25\ \rightarrow A_{s(provided)} = 6125\ mm^2$$

Checks:

- Reinforcement ratio
- Spacing
- $\phi P_n$



# Column Design

- Example

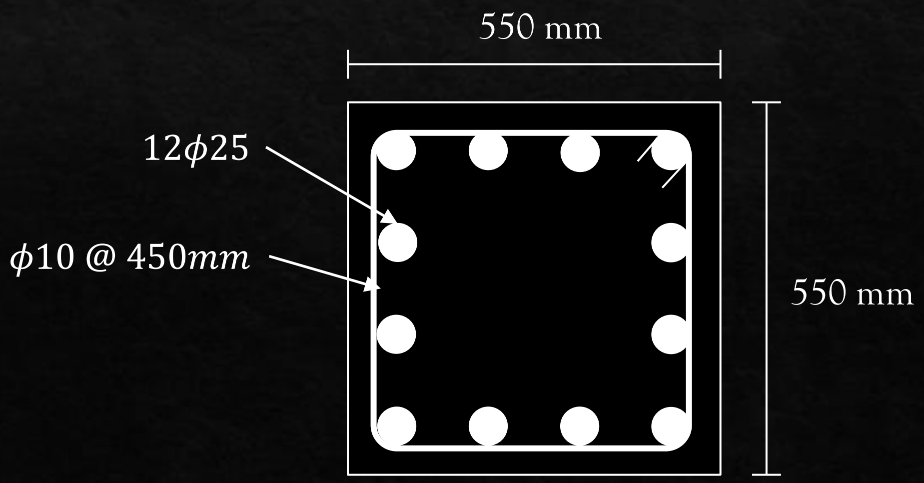
Design a non-slender square column which is subjected to a concentric 2300 kN and 1335 kN dead and live loads, respectively.

[Use $\rho = 0.02, f_y = 420\ MPa\ and\ f_c' = 28\ MPa$]

Ties:

Size → ϕ10 bar if longitudinal bar ≤ ϕ32 → Use $\phi$ 10 ties

Spacing → $\min \begin{cases} 16d_b \\ 48\ d_t \\ B \end{cases} \rightarrow \begin{cases} 500 \\ 480 \\ 550 \end{cases} \rightarrow use\ \ 450\ mm\ spacing$



# Column Design

- Example

Design a non-slender spiraled circular column which is subjected to a concentric 2300 kN and 1335 kN dead and live loads, respectively.

[Use $\rho = 0.02, f_y = 420\ MPa\ and\ f_c' = 28\ MPa$]

$$\phi P_n = r\ \phi[0.85\ f_c'(A_g - A_{st}) + f_y A_{st}]$$

- Solution:

$P_u = 1.2 * D + 1.6\ L = 4896\ kN$

$A_{st} = 0.02\ A_g, r = 0.85\ , \phi = 0.7$

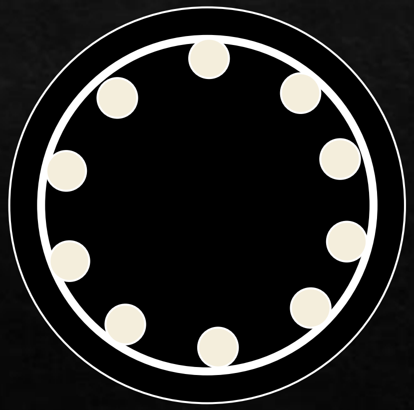
$\phi P_n = 0.85 * 0.7[0.85\ f_c'(A_g - 0.02A_g) + f_y * 0.02A_g$

$4896 * 10^3 = 0.8 * 0.65 * [0.85 * 28 * (0.98A_g) + 420 * 0.02 * A_g]$

$A_g = 259380\ mm^2 \rightarrow D = 574.7\ mm \sim 600\ mm$

Use this value and solve for $A_S = 3785\ mm^2$

$use\ 10\phi 22 \rightarrow A_{s(provided)} = 3870\ mm^2$



# Column Design

- **Example**

Design a non-slender spiraled circular column which is subjected to a concentric 2300 kN and 1335 kN dead and live loads, respectively.

[Use $\rho = 0.02, f_y = 420\ MPa\ and\ f_c' = 28\ MPa$]

- **Solution:**

Check:

$$\rho = \frac{3870}{\frac{\pi}{4}600^2} = 0.0134\ \ldots\ldots ok$$

$$\phi P_n = 0.8 * 0.7 * \left[0.85 * 28 * \left(\frac{\pi}{4}600^2 - 3870\right) + 420 * 3870\right]$$

$$\phi P_n = 4916\ kN > P_u \ldots\ldots ok$$

Spiral

Size → ϕ10

Spacing →*Table A14*→*Column diameter*=600 *mm*

spiral out *to out*=520 *mm*

→ Pitch *50 mm*